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THE EFFECT OF PROCESSING POULTRY MANURE
ON DISEASE AGENTS

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THE EFFECT OF PROCESSING POULTRY MANURE ON DISEASE AGENTS

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

In an attempt to solve the problem of disposing of agricultural wastes, the study described here investigated methods of disposing and treating poultry manure. Specifically, methods of employing poultry manure as litter for chickens were studied.

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THE EFFECT OF PROCESSING POULTRY MANURE ON DISEASE AGENTS

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INTRODUCTION

The interrelationships between poultry manure processing, bacterial load, pathogenicity and bird performance are poorly understood. Fanelli et al. (1970) reported that Salmonella infantis and S. typhimurium do not persist as long in built-up poultry litter as in fresh litter. The shed rate in birds on built-up litter suggests an inhibitory effect for salmonellae in the litter. Botts et al. (1952) noted that Salmonella pullorum and S. gallinarum lived longer in fresh litter than built-up litter, and that infectivity and mortality among chicks were lower on built-up litter than on fresh litter. Kennard and Chamberlain (1951) found that both growth rate and livability were superior when chicks were grown on built-up litter and that the prevention and/or control of coccidiosis was enhanced by the use of built-up litter. Schefferle (1965) reported that the number of organisms in built-up litter did not appear to be affected by age, temperature, moisture content or pH of the litter, but that organism type varied with pH and buffering capacity of the litter; alkaline conditions lowered the number of gram-negative bacteria and fungi. Condemnations resulting from leukosis generally were lower for broilers grown on reused litter, according to Chaloupka et al. (1968). Damp and/or

crusty litter produced foot-pad dermatitis in young turkeys according to Abbott et al. (1969). Ross (1968) reduced the bacterial population of reused litter with methyl bromide fumigation; however, the reduction in bacteria did not result in a significant improvement in body weight gain, feed conversion or livability. Two conclusions may be drawn from these and other less complete reports. Nonpathogenic microorganisms in used or recycled litter do not appear to influence the performance of chickens adversely to eight weeks of age. Reused and built-up litter tend to contribute to a biological system that partially inhibits the growth of microorganisms in the litter.

The purpose of the present investigation was two-fold: (1) to determine the effect of several litter management variants on bird performance to eight weeks of age; and (2) to investigate the survival of disease agents in variously treated poultry litters.

MATERIALS AND METHODS

Poultry Litter Managerial Programs. Two experiments, one utilizing 2,000 and the second 2,400 broiler-type male chickens, were conducted to compare the effects of various litter treatments on bird performance to eight weeks of age. In Experiment I, fresh pine shavings litter were compared to used pine shavings, used litter treated with a bacterial preparation (Litter-Life*) designed to aerobically digest animal waste and litter, used litter treated with an antifungal preparation (Myconox**), and used litter treated with both Litter-Life and Myconox. Litter treatments involving Litter-Life and Myconox followed manufacturers'

*Trade name of a product produced by Blenders, Inc., Lithonia, Georgia.

**Trade name of a product produced by Naremcro, Inc., P. O. Box 1572, Springfield, Missouri.

recommendations. The exact composition of Litter-Life and Myconox was not available to the researchers.

In Experiment II fresh shavings were added to once used litter (50/50) to serve as a control. This treatment was compared with twice used litter, twice used litter treated with Litter-Life, twice used litter treated with Myconox and twice used litter treated with Myconox and Litter-Life. Composted garbage was used as a sixth treatment. Garbage from which metal and large pieces of glass and plastic were removed was composted by Lone Star Organics, Inc., Houston, Texas, and was evaluated as a litter for poultry.

Myconox was added to the litter at the rate of 454 gms per 9 m^2 of floor space. Litter-Life was added to the litter at the rate of 22.7 kgs per 9 m^2 of floor space. Each litter additive was added to the litter and mixed thoroughly. The litter was then sprayed with water, piled and allowed to compost for one week. The litter was then spread in the floor pens to a depth of 10 cms. The same procedures were followed in both experiments.

Experiment III was a comparison of seven litter programs utilizing fresh pine shavings, fresh sand, a mixture of fresh sand and fresh shavings (50/50), fresh sand and used litter (50/50), pine peawings, cleaned rice hulls, and a mixture of cleaned rice hulls and used litter.

The same seven treatment groups used in Experiment III were utilized in Experiment IV, but attempts were made to recondition the litters by adding fresh shavings to two of the original four replications in Experiment III. The remaining two replicates had composted garbage added to the litter. Approximately one cubic meter of fresh shavings or composted

garbage was added to each of the pens. Each pen had 9 m² of floor space, and the depth of the litter in each pen was 10 cms.

Each treatment in Experiments I, II and III was replicated four times utilizing 100 birds per 9 m² of floor space. In Experiment IV each treatment was replicated twice. Body weight at eight weeks, feed conversion, livability and amount of caked litter were the criteria for evaluating the various litter programs. The amount of caked litter tends to contribute to condemnations and down-grading in broilers and is generally considered an undesirable litter characteristic. No attempt was made to relate the amount of litter caking to condemnations and down-grading because of processing difficulties.

Two additional litter evaluation studies were conducted in 1969 and 1970. These studies evaluated litters primarily of wood origin, and with varying particle sizes. These will be referred to as Experiments V and VI.

All treatments in Experiments I, II, III, V and VI were replicated four times and 100 broiler type male chickens were placed in each pen (replicate). Each treatment in Experiment IV was replicated twice. The birds were housed in a typical broiler house with a dirt floor and received a standard broiler-type ration. Heat was supplied the chicks from red infrared heat lamps.

Survival of Disease Agents in Composted Poultry Waste. In another series of experiments, chickens infected with selected pathogens (protozoa-coccidia, bacteria-Salmonella blockley, and a virus-Newcastle disease) were placed on litter and allowed to seed the litter by natural elimination of the pathogen. After determining by laboratory means that the litter

was heavily infected, the birds were withdrawn and the litter was subjected to a treatment which consisted of "time" (days untreated litter left idle) and "composting". Litter samples were collected at periodic intervals and processed for recovery of disease agents, and checked for infectivity in chickens. Incrossbred males were utilized in all trials. The methodology specific to each of the three pathogens follows.

Coccidiosis--Five to 100 susceptible birds were inoculated intra-esophageally with sub-lethal numbers (10,000 to 50,000 per bird) of sporulated oocysts and placed in floor pens (9 m^2) on clean litter 10 cms deep. Natural seeding of the litter with oocysts was allowed to take place during a 14 to 28 day post inoculation period, after which the chickens were removed. The seeded litter was subjected to the treatments of "time" and "compost". Litter samples were collected at periodic intervals, i. e., pre-seeding, during seeding (Interium), at bird withdrawal, and during the post withdrawal period (P.W. Treatment); and the oocysts present in these samples were sporulated and concentrated. Susceptible chickens were placed in treatment groups and exposed to equal numbers of these sporulated oocysts to determine the effects of litter composting on oocysts infectivity. Eight days post exposure, the birds were killed and examined for lesions of coccidiosis. Lesions were scored negative to 4+ depending upon severity. Intestinal contents were collected and qualitatively and quantitatively examined for oocysts. Eimeria tenella, E. acervulina, and E. maxima as a group infect the entire small intestine and ceca (ceca, upper half of small intestine, middle and lower portion of small intestine, respectively), and hence were included as part of the survival of disease agent experiments.

Salmonella--In each of two experiments, an 18 hour broth (Brain Heart Infusion) culture of S. blockley was diluted 1 to 6 in BHI broth. Seventy-eight to 111, 4 to 6-week old chickens were given 0.5 ml of organisms intraesophageally and then assigned to each of two pens. Natural seeding of litter with the organism was allowed to take place during a 14-day post inoculation period after which the chickens were removed from the pens. The litter was then subjected to the treatments of "time" (one pen) and "compost" (one pen). Litter samples were collected at periodic intervals, i. e., pre-seeding, during seeding (Interium), at bird withdrawal, and during the post withdrawal (P.W.) treatment period, and cultured for S. blockley. Rectal swabs were collected and cultured from the seeder chickens during the seeding period and at withdrawal to determine if seeding was taking place.

Newcastle Disease--Fifty birds in each of 2 pens were exposed to DK 1155 Newcastle disease virus (NDV) by the following method: virus was applied by tracheal swab to 10 birds, virus was applied by wing web swab to 10 birds, and virus was applied to all birds by the drinking water method. This method of exposure was used to insure inoculation of the birds. Natural NDV seeding of the litter was allowed to take place during a 24-day post exposure period after which the birds were removed and the litter subjected to treatments of "time" (one pen) and "compost" (one pen). Litter samples were collected at periodic intervals, i. e., pre-seeding, during seeding (Interium), at bird withdrawal and during the P.W. treatment period. Attempts were made to isolate NDV through inoculation of embryonated chicken eggs. Tracheal swabs were collected from seeder chickens during the seeding and withdrawal period to determine

if NDV seeding was taking place. After the litter treatment was completed, sentinel chickens were placed on untreated and on composted litter for three weeks to monitor for residual NDV.

Ultraviolet Light Treatment--A standardized culture (50,000 sporulated oocysts/ml) of E. tenella was divided into aliquots which were subjected to U.V. exposure for the following time intervals:

1. Untreated control
2. U.V. exposure - 15 minutes
3. U.V. exposure - 30 minutes
4. U.V. exposure - 60 minutes
5. U.V. exposure - 120 minutes
6. U.V. exposure - 15 hours

Prior to exposure each aliquot was placed in a large petri dish (depth of aliquot was approximately 25 mm), covered with Saran Wrap, and exposed to the U.V. light source at a distance of 15 cms. Following exposure, 10 three-week old chickens were inoculated intraesophageally with each of the aliquots (50,000 oocysts per bird). The birds were examined daily during a seven-day post exposure period. Birds which died were examined for lesions of coccidiosis. Those surviving also were killed and examined for lesions.

RESULTS AND DISCUSSION

Poultry Litter Managerial Programs. Initially, three litter composting procedures were evaluated (Table 1, Experiment I). One procedure utilized a bacterial preparation (Litter-Life) designed to aerobically digest poultry waste and organic litter. The second utilized a fungicidal complex (Myconox) which was mixed into the litter. A third treatment combined both Myconox

and Litter-Life. In all cases the litter was allowed to compost for one week before being used. Fresh and once used litter were utilized as controls.

Broilers grown to eight weeks of age on once used litter and once used litter composted with Litter-Life were much superior in growth (1730 and 1712 gms, respectively) and feed efficiency (2.09 and 2.03, respectively) to birds grown on fresh pine shavings (1603 gms) and on used litter composted with fungicide (1644 gms) (Table 1, Experiment I). No statistically significant differences in growth and feed efficiency were obtained between the groups grown on once used litter and once used litter composted with Litter-Life, but these two groups were significantly different from all other groups. Similarly, no statistically significant differences were obtained between the fresh pine shavings control groups and the birds grown on once used litter composted with the fungicide, although the poorest performance was obtained in those birds grown on fresh pine shavings. Livability was not influenced by the litter treatment practices.

Of interest is the fact that used litter treated with Litter-Life had approximately half the amount of caked litter (18.6 kgs) as compared to the other groups (30.6 to 41.3 kgs) (Figure 1). The variation between pens treated alike was as large as the variation between treatments resulting in the caked litter means not differing statistically (Table 1, Experiment I). The consistency of differences among the caked litter means do however attract attention and suggest that Litter-Life, a bacterial preparation designed to rapidly digest organic matter, may have value in composting litter.

In Experiment II, twice used litter was composted as in Experiment I. All litters used were one grow-out lot older. In addition, composted garbage was added to the experiment for evaluation. These birds were grown out during the coldest part of the year, a factor which would tend to alter the growth pattern of the birds and effect litter condition.

Broilers grown on litter composted with Litter-Life and Myconox (fungicide) grew best to eight weeks of age (Table 1, Experiment II). No statistically significant difference was noted between these three means. The birds grown on composted litter treated with fungicide performed best and significant differences in feed utilization were noted between this group and the remaining five treatment groups. The chicks grown on litter containing clean shavings, as in Experiment I, grew the poorest. Livability was outstanding in this experiment.

A greater amount of caked litter was observed in Experiment II than in Experiment I, and the variability in caked litter among replicate pens was considerably smaller in Experiment II (Table 1). The composted garbage litter pens and the pen treated with a combination of Litter-Life and Myconox (Figure 2) had a significantly greater amount of caked litter than the fresh pine shavings control pens.

The observations from Experiments I and II suggest that birds grown to eight weeks of age perform as well or better on old litter as those grown on fresh litter, and support the findings of Kennard and Chamberlain (1951), as well as others (abstracts), that growth rate and livability of chickens grown on old built-up litter are generally superior to those grown on fresh or newly built-up litter. The litter used in the current studies must be classified as newly built-up litter and was superior to

fresh shavings when evaluated on the basis of broiler performance. Litter-Life may have some merit in the composting process, particularly since there was reduced caking of litter when this material was used. These data strongly suggest that it is possible to re-use litter to advantage if microorganisms pathenogenic to birds can be controlled.

Seven litter combinations were compared in Experiment III as to their suitability for growing birds. Good litter sources such as pine shavings are becoming scarce and expensive. Hence, new and acceptable litter sources for poultry must be located and tested.

Broilers grown on pine peelings grew extremely well (1734 gms) with an excellent feed efficiency (Table 2). As might have been expected, birds grown on sand performed significantly poorer (1507 gms) than those on the remaining six litter treatments. When used litter or clean shavings were added to sand, body weight and feed efficiency improved materially over sand alone as a litter. Birds grown on rice hulls also failed to perform well. Rice hull litter and fresh shavings litter produced the least caked litter, and significantly so. The litters containing sand, and the pine peelings litter, showed an excessive amount of caking.

Experiment IV was an extension of Experiment III (Table 3). Each of the seven litters used in Experiment III was reconditioned with either fresh pine shavings or composted garbage and then used to grow out a second lot of broilers. The groups of broilers grown on sand and once used litter charged with fresh shavings, on pine peelings once used charged with fresh shavings, grew well and had excellent feed efficiencies (Table 3). The birds on sand litter grew the poorest. Significant differences in livability were noted; however, these could not be

associated with type of litter. Pine peelings once used and reconditioned by adding shavings had significantly less caked litter than the other treatment groups.

Reconditioning the seven litters with composted garbage resulted in an altered growth response (Table 3). In this case, birds grown on sand plus composted garbage grew best and had the highest feed efficiency. The birds grown on sand and twice used litter and on rice hulls and used litter grew the poorest. Sand litter caked the worst (82.6 kg), while once used litter, sand plus once used litter and pine peelings, produced the least caking.

When birds grown on litters reconditioned with fresh shavings were compared with birds on litter conditioned with composted garbage, growth rate and feed efficiency favored the shavings reconditioned litter (Table 3). Body weights were 1629 and 1542 gms and feed efficiencies were 2.24 and 2.33 gms feed per gm of gain for shavings and composted garbage, respectively. Litter condition as measured by caking was significantly better when shavings were used to recondition the litter. Livability was best when the litter was reconditioned with composted garbage.

The results of Experiment V indicate that there were no statistically significant differences in the performance of male broilers grown on pine shavings, cleaned rice hulls, processed hardwood bark, pine bark (<1") and milled pine bark when evaluated on the basis of body weight, mortality, feed conversion and caked litter (Table 4). The variance among replicates treated alike was almost as great as the variance among treatments. Feed efficiency values, particularly for the pine shavings and rice hull groups do not fit expected values and probably can be explained on the basis of

excessive feed wastage. The data on market grade are difficult to interpret biologically. Apparently, all birds which were free of breast blisters at eight weeks of age were classified as U.S. grade A. U.S. grade standards for live broilers include greater detail than was used in this particular experiment. The grade means presented in Table 4 do differ significantly when measured statistically. Breast blister incidence can be attributed to the size of the birds and the condition of the litter rather than type of litter used in the experiment.

Average performance values for the birds grown on a sixth set of eight litter combinations are presented in Table 5. Body weight was not significantly influenced by the type of litter used. Birds on hardwood bark litter were uniformly heavier than the remaining groups, while the birds in the control pen and the pens with used rice hull litter had the smallest average body weight. Livability differences noted could be attributed to type of litter used in this case.

Live market grade (U.S. Grade A) was not good in this study because of the high incidence of breast blisters and a lack of fleshing and finish in the birds. The market grade differences noted in Table 5 are not statistically significant. Breast blister incidence, however, was extremely high in those birds grown on used shavings, used course milled pine shavings, and on hardwood bark plus Myconox. Because of the magnitude of the within treatment variation, the differences in blister incidence were not statistically significant. No significant differences were noted between used and new litter, between the old litters, or between the new litters for any of the traits measured. Myconox (fungicide) added to hardwood bark litter had no beneficial effect on the performance of the broilers.

Seeger et al. (1951) have reported the most extensive evaluation of litter materials for poultry to-date. Their study indicated that litters of organic origin are superior to litters of inorganic origin. They further report that litters of inorganic origin increase dustiness in broiler pens, which in turn increases the severity of respiratory diseases. They indicated that litters should be fine in texture, dry, light in weight, and relatively free of dust. The current study would tend to support these observations. Birds grown on sand alone generally performed poorly. The organic litters studied, when evaluated across all experiments, would appear to be satisfactory poultry litters. Birds grown on used and composted litters generally were heavier at eight weeks of age than similar birds grown on new or fresh litter materials. Used or built-up litters contribute something, probably unidentified growth factors and certain B-complex vitamins, giving increased growth over that of chickens on new litter. The biological mechanisms involved in composted or built-up litter have not been determined to date. Composted garbage can be used for poultry litter; although in these studies the performance of birds on composted garbage was not outstanding. In no experiment was dust a problem. The amount of caked litter would indicate that there was ample moisture in the pens to keep dust minimal.

Survival of Disease Agents in Composted Poultry Waste. Chickens infected with selected pathogens (protozoa-coccidia, bacteria-Salmonella b ockley, and a virus-Newcastle disease) were grown on clean litter and allowed to seed the litter by natural elimination of the pathogen. The seeder chickens were withdrawn, the litter composted, and susceptible birds placed on the composted litter. With the exception of Experiment I,

untreated (non-composted) litter served as the control. In addition to composting, "time" following withdrawal of seeder birds was evaluated as a variable utilizing the control pens. Only one pathogen was used in each experiment. The final experiment utilized ultraviolet light treatment as a mechanism for destroying coccidia.

Coccidiosis--Eimeria tenella was the infective agent in four experiments. Infectivity of composted and untreated litter was determined in three ways: evaluation of lesions (negative to 4+) in the intestines and ceca of test birds, qualitative yield (absence or presence) of oocysts in intestinal contents of test birds and quantitative yield (actual number) of oocysts per gram of intestinal content of test birds.

According to Tables 6 and 7 interium seeding was successful in infecting the litter with E. tenella. Post withdrawal composting of the litter appeared to have some destructive effect on E. tenella when compared with post withdrawal untreated litter. The birds given oocysts derived from composted litter generally had no lesions in the gut; however, coccidia could be isolated. Composting apparently was effective in destroying the oocysts in the seeded litter; however, infectivity of the post withdrawal untreated litter (control) also was considered mild. Mortality was negligible in both the post withdrawal compost and untreated groups. An evaluation of the P.W. untreated groups represented in Table 7 suggests that during the period from 40 to 49 days, infectivity as measured by presence of lesions was decreasing.

E. acervulina was the second coccidia utilized. The litter seeding procedure was extremely effective as evidenced by the production of 4+ lesions in the birds given oocysts derived from litter collected during

the seeding period (Table 8). Post withdrawal composting of litter was not completely effective in destroying E. acervulina. Susceptible birds given oocysts derived from the P.W. untreated litter were completely negative when examined. The 41 days post exposure may have been sufficient to destroy E. acervulina (the "time" factor), or composting of the untreated litter occurred unknowingly. There was no question about the infectivity of the litter following the withdrawal of the seeder birds.

A sixth experiment utilized E. maxima (Table 9). The results of this experiment are questionable because of potassium dichromate toxicity; however, infectivity of untreated and composted litter was the same 39 to 40 days post withdrawal. There was a definite decrease in lesions and number of oocysts observed in birds given oocysts derived from untreated litter 49 days post withdrawal.

Salmonella--Salmonella blockley was utilized to determine the effect of litter composting on a bacterium. The results of the salmonella trial are given in Table 10. Although S. blockley could be isolated from the seeder birds throughout the seeding period, recovery rates dropped markedly after the first sampling period. This suggests that S. blockley is a transient inhabitant of the intestinal tract in most birds. Ability to recover S. blockley from seeded litter was lost rapidly with time, for in no instance were organisms recovered at the time of bird withdrawal or during the post withdrawal period (Table 10). These results suggest that S. blockley is not a suitable organism to use in the study of litter management.

Newcastle Disease--Newcastle disease virus can produce severe losses in chickens. Its epidemiology is such that all poultrymen immunize their

birds against Newcastle disease. Hence, it should be a suitable virus for litter management studies. Although Newcastle disease virus could be readily isolated during the seeding period, all attempts to isolate Newcastle virus from seeded litter were negative (Table 11). Sentinel birds placed on untreated (fine) and composted litter failed to develop Newcastle disease. Likewise, attempts to isolate Newcastle virus from the birds were unsuccessful. Like S. blockley, Newcastle disease virus is a poor agent to use in these type studies because of the rapidity of inactivation.

Composting Temperatures--Typical litter composting temperatures are presented in Figures 3 and 4 for the period June 25 to July 25, early summer months. Three observations can be drawn from Figures 3 and 4. There was considerable pen to pen variation in compost temperatures (as much as 17°C variation) even though the initial litter temperatures were essentially the same on June 25. Secondly, temperature elevation due to composting lasted for approximately six days and did not exceed 62.5°C average 3-day temperature as a maximum in these studies. Thirdly, the litter temperatures approached equality on July 12 and July 24. These observations suggest that the composting process is not simple and is subject to considerable variation. Pen 4 had the highest compost temperature (Figure 3), yet this temperature failed to fully inactivate E. acervulina (Table 7). E. tenella was much easier to inactivate, despite lower composting temperatures. The high compost temperatures presented in Figure 4 mean little since S. blockley could not be isolated in the post withdrawal untreated litter.

Conclusions--These observations suggest that the composting process is reasonably complex and subject to considerable variation. A quality

control composting program must be developed for these type studies. Composting as practised, did destroy microorganisms and reduce infectivity. Likewise, "time" (idle litter-untreated) was an important factor in reducing infectivity of litter. Attempts should have been made to produce and evaluate higher litter composting temperatures.

These studies indicated that many infectious agents are not suitable for litter management studies. Even the "hardy" coccidia lose quantitative infectivity rapidly with time.

These composted litter treatments could not be compared with those of Fanelli et al. (1970), Botts et al. (1952) and Schefferle (1965) who used old built-up litters. The results of this study do tend to agree with their findings in that in the current study infectivity of seeded litters was reduced. The mechanism of microorganism destruction, however, was probably different. The results from rapid composting would be expected to be different from the composting process occurring in old built-up litter.

Ultraviolet Litter Treatment. Ultraviolet light treatment of litter to destroy E. tenella has distinct possibilities (Table 12). U.V. treatment of E. tenella coccidia for 30 minutes or less failed to reduce mortality in exposed birds (4+ lesion scores). Litter treatment for 60 minutes or more reduced infectivity as measured by mortality and lesion scores (3+ or less). This study suggests that U.V. light treatment of litter may have merit in reducing the infectivity of pathogens.

SUMMARY

This study consisted of two phases: (1) to study management variants during composting of poultry wastes of different origins on the physical and pathogenic nature of litter materials and broiler performance; (2) to investigate the survival of disease agents in composted poultry wastes and subsequent infectivity of these agents on susceptible chickens. The following observations were noted:

1. Birds grown to eight weeks of age grew as well or better on used litter than on fresh litter.
2. A bacterial preparation designed to aerobically digest poultry waste and organic matter (Litter-Life) may be an aid to the litter composting process. Less caked litter was obtained when litter was composted with Litter-Life.
3. The use of sand litter generally resulted in reduced growth rate and feed efficiency. Sand litter and sand litter mixed with shavings produced large amounts of caked litter.
4. Properly composted garbage can be used for poultry litter. In these studies broiler performance was satisfactory when composted garbage was used as litter.
5. Reconditioning of used litter was best accomplished with fresh pine shavings. Composted garbage was inferior to pine shavings as a composting agent.
6. Rice hulls, fine milled pine shavings, course milled pine shavings, cottonwood mixture, hardwood bark and pine bark are suitable litters for broiler production. There could be problems with breast blisters when certain of these litters are used.

7. Both litter composting and time partially reduced coccidia infectivity of coccidia seeded litter. Three types of coccidia, E. tenella, E. acervulina and E. maxima, were evaluated.

8. Salmonella blockley was an unsuitable organism for litter management studies. S. blockley apparently is a transient inhabitant of the intestinal tract in most birds and its survival in litter is limited.

9. Sentinel birds placed on time treated (untreated) and on composted litter failed to develop Newcastle disease. The two litters had previously been seeded with Newcastle disease virus.

10. Considerable variation in compost temperatures occurred in these studies. The composting process is not a simple one and must be refined for these type investigations.

11. Ultraviolet treatment for 30 minutes or more reduced infectivity of an E. tenella inoculum. Mortality was reduced in birds inoculated with U.V. treated (30 minutes or more) oocysts. Ultraviolet light may be useful in reducing infectivity of pathogens in contaminated litter.

12. Not all infectious agents are suitable for litter management investigations. It is suggested that internal parasites, a danger in using built-up litter, may be more desirable organisms for these type studies.

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Table 1. The effect of various litter treatments on the performance of broiler-type male chickens to 8 weeks of age

Litter Treatments	No. Birds	Mean 8-Week Wt. (gm)	Livability (%)	Gm Feed Per Gm Wt.	Caked** Litter (kg)
Experiment I					
Control -- Fresh Shavings	400	1603 ^{b*}	93.5 ^{a*}	2.16 ^{bc*}	30.6 ^{a*}
Control -- Once Used Litter	400	1730 ^a	94.5 ^a	2.09 ^{ab}	41.3 ^a
Litter-Life Treated Used Litter	400	1712 ^a	94.2 ^a	2.03 ^a	18.6 ^a
Fungicide Treated Used Litter	400	1644 ^b	94.2 ^a	2.17 ^{bc}	40.2 ^a
Fungicide + Litter-Life Treated Used Litter	400	1621 ^b	94.0 ^a	2.23 ^c	18.6 ^a
Experiment II					
Control -- Old Litter + Fresh Shavings	400	1559 ^b	98.3 ^a	2.28 ^b	54.2 ^b
Control -- Twice Used Litter	400	1575 ^b	96.3 ^a	2.30 ^b	59.3 ^{ab}
Twice Used Litter + Litter-Life	400	1614 ^{ab}	98.5 ^a	2.22 ^{ab}	58.8 ^{ab}
Fungicide Treated Used Litter	400	1646 ^a	97.3 ^a	2.16 ^a	59.9 ^{ab}
Fungicide + Litter-Life Treated Used Litter	400	1591 ^{ab}	98.3 ^a	2.29 ^b	61.9 ^a
Composted Garbage	400	1575 ^b	98.5 ^a	2.27 ^b	64.5 ^a

*Means with different letters differ significantly at the 0.05 level of probability.

**Mean caked litter per pen (replicate).

Table 2. A comparison of the effects of seven litter programs on broiler performance (Experiment III)

Litter Treatments	No. Birds	Mean 8-Week Wt. (gm)	Livability (%)	Gm Feed Per Gm Wt.	Caked** Litter (kg)
Control-Fresh Shavings	400	1603 ^{bc*}	93.5 ^{a*}	2.16 ^{b*}	30.6 ^{a*}
Sand	400	1507 ^d	93.5 ^a	2.31 ^d	136.2 ^b
Sand and Shavings (50/50)	400	1621 ^b	94.5 ^a	2.15 ^b	100.1 ^b
Sand and Used Litter (50/50)	400	1653 ^b	94.0 ^a	2.18 ^b	109.4 ^b
Pine Peelings	400	1734 ^b	93.8 ^a	2.09 ^a	134.1 ^b
Cleaned Rice Hulls	400	1557 ^c	94.8 ^a	2.28 ^{cd}	23.3 ^a
Rice Hulls and Used Litter	400	1562 ^c	94.5 ^a	2.23 ^{bc}	24.8 ^a

*Means with different letters differ significantly at the 0.05 level of probability.

**Mean caked litter per pen (replicate).

Table 3. The effect of used litters reconditioned with fresh shavings or composted garbage on broiler performance (Experiment IV)

Litter Treatments	Fresh Shavings ¹				Composted Garbage ²		
	Mean 8-Week Wt. (gm)	Livability (%)	Feed Conv.	Caked** Litter (kg)	Mean 8-Week Wt. (gm)	Livability (%)	Feed Conv.
Control-Once Used Litter	1589 ^{b*}	97.5 ^{a*}	2.23 ^{c*}	46.5 ^{b*}	1530 ^{bc*}	99.0 ^{a*}	2.33 ^{bc*}
Sand +	1516 ^c	99.0 ^a	2.31 ^{de}	46.5 ^b	1634 ^a	98.0 ^a	2.24 ^a
Sand and Once Used Litter +	1757 ^a	97.0 ^a	2.04 ^a	40.2 ^b	1584 ^b	96.0 ^a	2.29 ^{ab}
Sand and Twice Used Litter +	1575 ^b	93.5 ^b	2.40 ^f	41.3 ^b	1471 ^d	98.0 ^a	2.42 ^d
Pine Peelings Once Used +	1734 ^a	97.0 ^a	2.13 ^b	24.8 ^a	1530 ^{bc}	97.0 ^a	2.37 ^{cd}
Rice Hulls Once Used +	1621 ^b	93.5 ^b	2.34 ^{ef}	40.2 ^b	1562 ^b	98.5 ^a	2.28 ^{ab}
Rice Hulls and Used Litter +	1612 ^b	98.5 ^a	2.25 ^{cd}	43.3 ^b	1485 ^{cd}	97.5 ^a	2.40 ^d
Shavings vs. Garbage	1629 ^{m*}	96.6 ^m	2.24 ^m	40.4 ^m	1542 ^{n*}	97.7 ⁿ	2.33 ⁿ
							68.4 ⁿ

¹Fresh shavings added to bring litter depth to 10 cm.

²Composted garbage added to recondition the litter and to bring litter depth to 10 cm.

*Means with different letters differ significantly at the 0.05 level of probability.

**Mean caked litter per pen (replicate).

Table 4. An evaluation of litters for broilers (Experiment V)

Treatments (Litters)	Mean 8-Week Wt. (gm)	Feed Efficiency (feed/weight)	Livability (%)	U.S. Grade A (%)	Caked** Litter (kg)
Pine Shavings	1861	2.54 ^{c*}	89.0 ^{a*}	100.0 ^{a*}	136.4
Rice Hulls	1975	2.29 ^b	96.0 ^a	83.3 ^b	146.8
Processed Hardwood					
Bark	1843	2.18 ^a	93.5 ^a	73.3 ^c	159.5
Pine Bark (1")	1853	2.14 ^a	95.0 ^a	86.7 ^b	122.3
Milled Pine Bark	1907	2.20 ^a	96.0 ^a	72.9 ^c	110.5

(Weather conditions -- Cool and Damp)

*Means with different letters differ significantly at the 0.05 level of probability.

**Mean caked litter per pen (replicate).

Table 5. A comparison of various types of new and used litters for broilers (Experiment VI)

Treatments (Litter)	Litter Use	Mean 8-Week Wt. (gm)	Livability (%)	U.S. Grade A (%)	Breast Blisters (%)
Shavings	Used	1249 ^{a*}	86.5 ^{b*}	84.5 ^{a*}	12.1
Rice Hulls	Used	1189 ^a	93.5 ^a	77.9 ^a	9.7
Fine Milled S.P.	Used	1212 ^a	88.0 ^b	81.2 ^a	6.8
Course Milled S.P.	Used	1267 ^a	95.5 ^a	76.0 ^a	14.6
Cottonwood Mixture	New	1230 ^a	98.0 ^a	80.7 ^a	9.1
Hardwood Bark	New	1353 ^b	95.0 ^a	76.8 ^a	9.1
Hardwood Bark					
Myconox	New	1258 ^a	95.0 ^a	69.5 ^a	15.8
Control	New	1180 ^a	83.0 ^b	76.0 ^a	7.2

*Means with different letters differ significantly at the 0.05 level of probability.

Table 6. Oocysts derived from litter naturally seeded with coccidia (E. tenella). Infectivity to susceptible chickens (Experiment I)

Litter Treatment	Samples Collected (Days post exposure)	Infectivity*		
		Lesions	Oocyst Yield	
			Qual.	Quant.**
Preseeding	0	Neg	Neg	-
Interium Seeding	8	4+	Pos	-
Withdrawal	31	Neg	Pos	-
Composted	64	Neg	Pos	-

*Each of 10 chickens inoculated with 50,000 sporulated oocysts (Preseeded litter was negative).

**Not determined.

Table 7. Oocysts derived from litter naturally seeded with coccidia (E. tenella). Infectivity to susceptible chickens (Experiment II)

Litter Treatment	Samples Collected (Days post exposure)	Infectivity*		
		Lesions	Oocyst Yield	
			Qual.	Quant.**
Preseeding	0	Neg	Neg	Neg
Interium Seeding	15	4+	Pos	6,500,000
Interium Seeding	22	2+	Pos	2,850,000
Withdrawal	28	±	Pos	20,000
P.W. Untreated	40	±	Pos	<10,000
P.W. Composted	39	Neg	Neg	Neg
P.W. Untreated	49	Neg	Pos	10,000
P.W. Composted	49	Neg	Neg	Neg

*Each of 10 chickens inoculated with 50,000 sporulated oocysts (Preseeded litter was negative).

**Oocyst yield/gram of intestinal content.

Table 8. Oocysts derived from litter naturally seeded with coccidia (E. acervulina). Infectivity to susceptible chickens (Experiment III)

Litter Treatment	Samples Collected (Days post exposure)	Lesions	Infectivity*	
			Oocyst Yield	
			Qual.	Quant.**
Preseeding	0	Neg	Neg	Neg
Interium Seeding	15	4+	Pos	30,000
Interium Seeding	22	4+	Pos	50,000
Withdrawal	28	4+	Pos	<10,000
P.W. Untreated	41	Neg	Neg	Neg
P.W. Composted	39	Neg	Pos	10,000

*Each of 10 chickens inoculated with 100,000 sporulated oocysts (Preseeded litter was negative).

**Oocysts yield/gram of intestinal content.

Table 9. Oocysts derived from litter naturally seeded with coccidia (E. maxima). Infectivity to susceptible chickens (Experiment IV)

Litter Treatment	Samples Collected (Days post exposure)	Lesions	Infectivity*	
			Oocyst Yield	
			Qual.	Quant.**
Preseeding	0	Neg	Neg	Neg
Interium Seeding	15	4+	Pos	12,420,000
Interium Seeding	22	2+	Pos	4,640,000
Withdrawal	28	1+	Pos	400,000
P.W. Untreated	40	1+	Pos	10,000
P.W. Composted	39	1+	Pos	<10,000
P.W. Untreated	49	±	Pos	<10,000
P.W. Composted***	49	-	-	-

*Each of 10 chickens inoculated with 50,000 sporulated oocysts (Preseeded litter was negative).

**Oocyst yield/gram of intestinal content.

***No results due to K dichromate toxicity.

Table 10. The isolation of S. blockley from litter naturally seeded by experimentally infected chickens

Litter Treatment	Samples Collected (Days post exposure)	Culture Results*
Experiment I		
Preseeding	0	Negative
Interium Seeding	5	Negative
Withdrawal	14	Positive
P.W. Untreated	32	Negative
P.W. Composted	32	Negative
Experiment II		
Preseeding	0	Negative
Interium Seeding	6	Positive
Withdrawal	13	Negative
P.W. Untreated	15	Negative
P.W. Composted	15	Negative
P.W. Untreated	17	Negative
P.W. Composted	17	Negative
P.W. Untreated	27	Negative
P.W. Composted	27	Negative

*Rectal swabs collected from seeder birds were positive at the 6 day post exposure and at the 13 day withdrawal collection period.

Table 11. The isolation of Newcastle disease virus from litter naturally seeded by experimentally infected chickens

Litter Treatment	Samples Collected (Days post exposure)	NDV Isolation Results*	
		In Embryonated Eggs	In Birds
Preseeding	0	Neg	-
Interium Seeding	6	Neg	-
Interium Seeding	13	Neg	-
Withdrawal	24	Neg	-
P.W. Untreated	49	-	Neg
P.W. Composted	49	-	Neg

*ND virus was readily re-isolated from tracheal swabs collected from the seeder birds.

Table 12. Morbidity and mortality in birds exposed to U.V. light treated E. tenella oocysts

Litter Treatment	Mortality*	Average Lesion Score**
Untreated	6/10	4+
U.V. - 15 minutes	7/10	4+
U.V. - 30 minutes	5/10	3+
U.V. - 60 minutes	2/10	3+
U.V. - 120 minutes	3/10	3+
U.V. - 15 hours	1/10	2+

*Numerator - birds died; Denominator - total birds.

**Includes both dead and surviving birds.

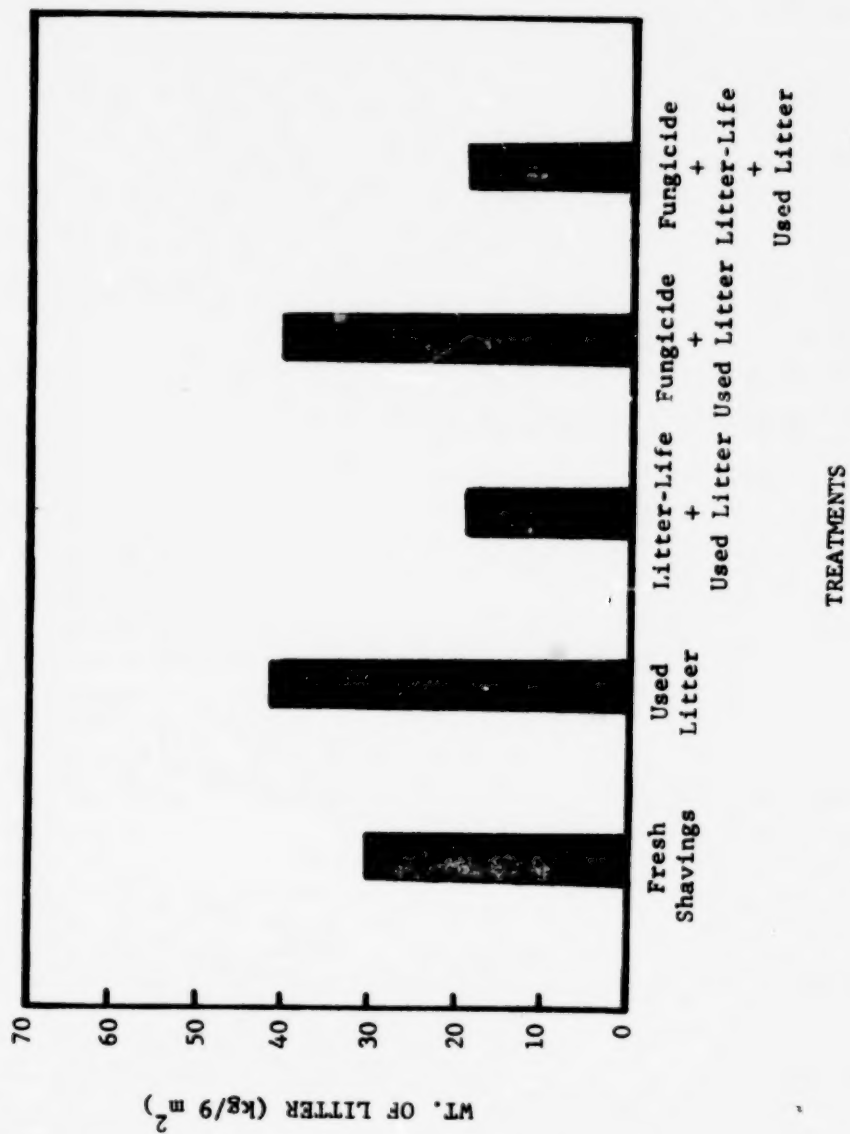


Figure 1. Effect of various litter treatments on litter absorbency and caking (Experiment I).

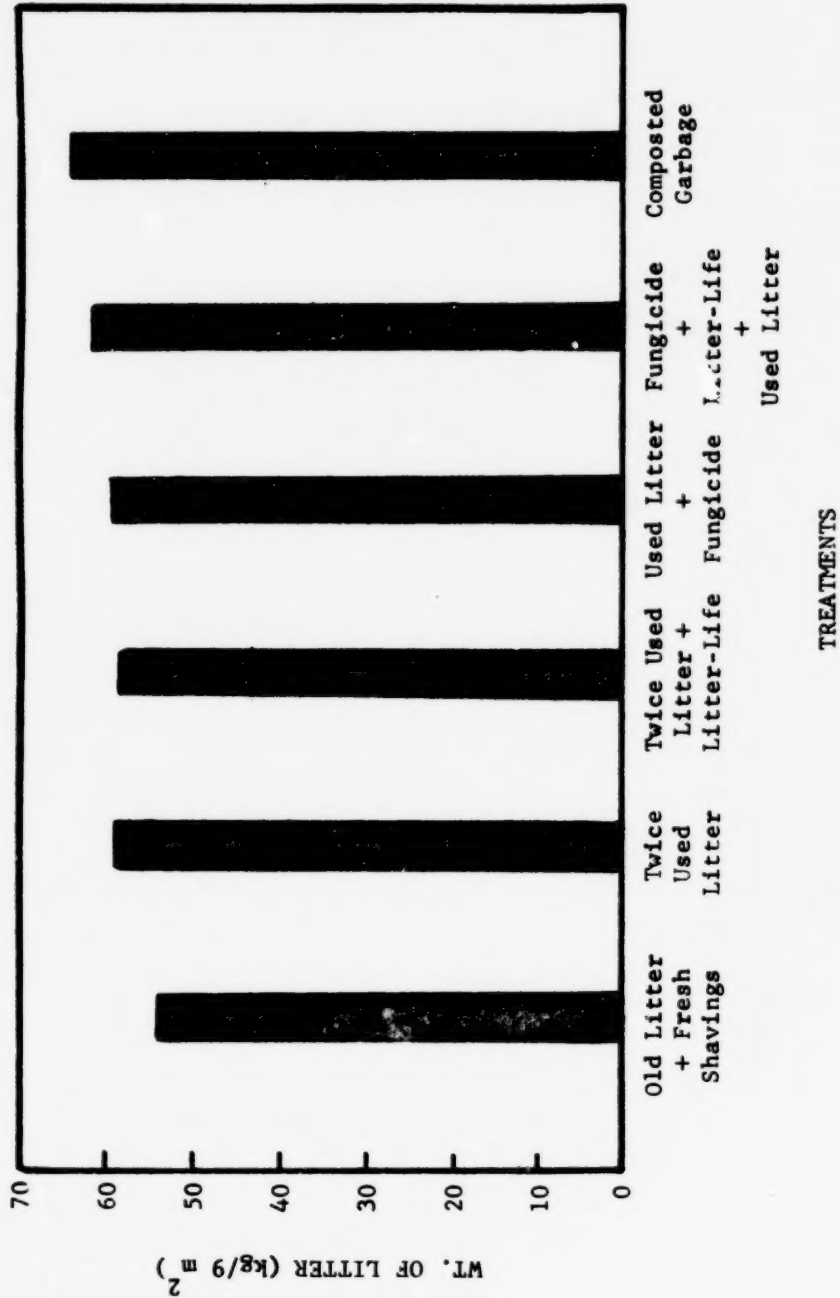


Figure 2. The effect of various litter treatments on litter absorbency and caking (Experiment II).

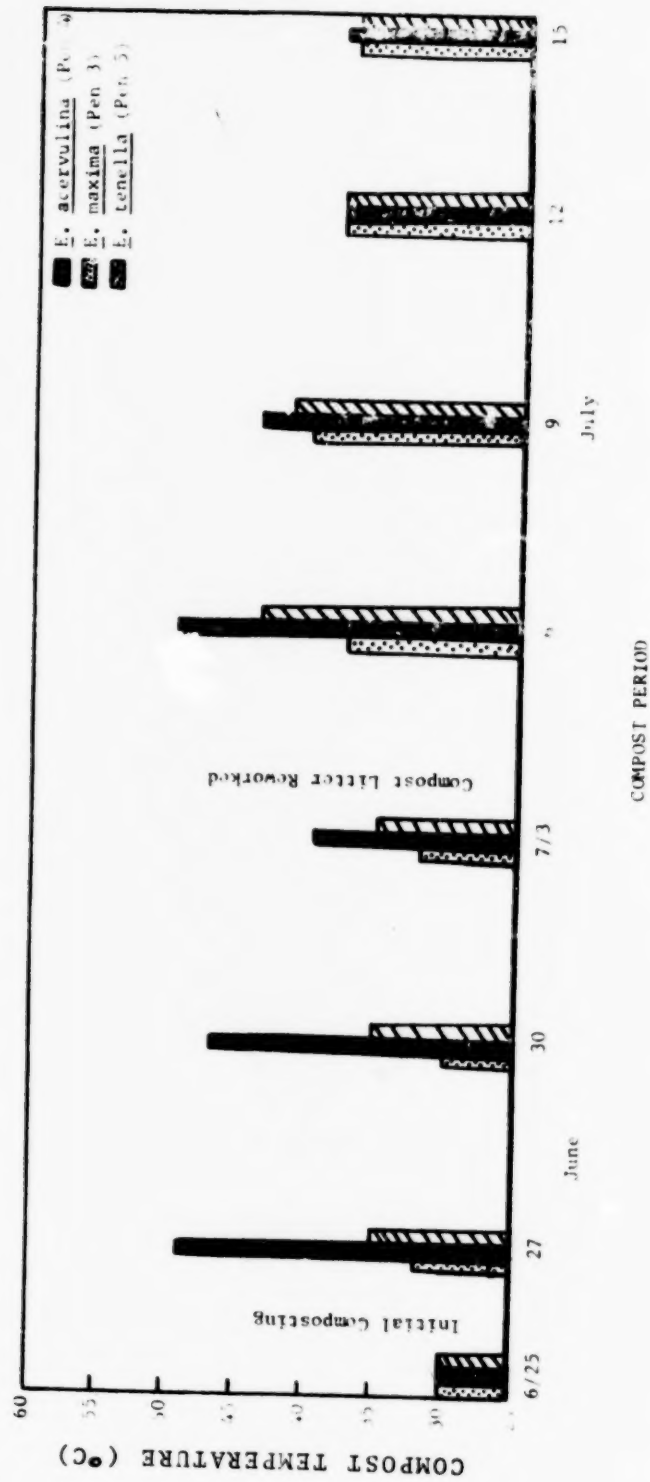


Figure 3. Average compost temperatures for E. tenella, E. maxima and E. acervulina seeded litters (Each bar is a three day average temperature).

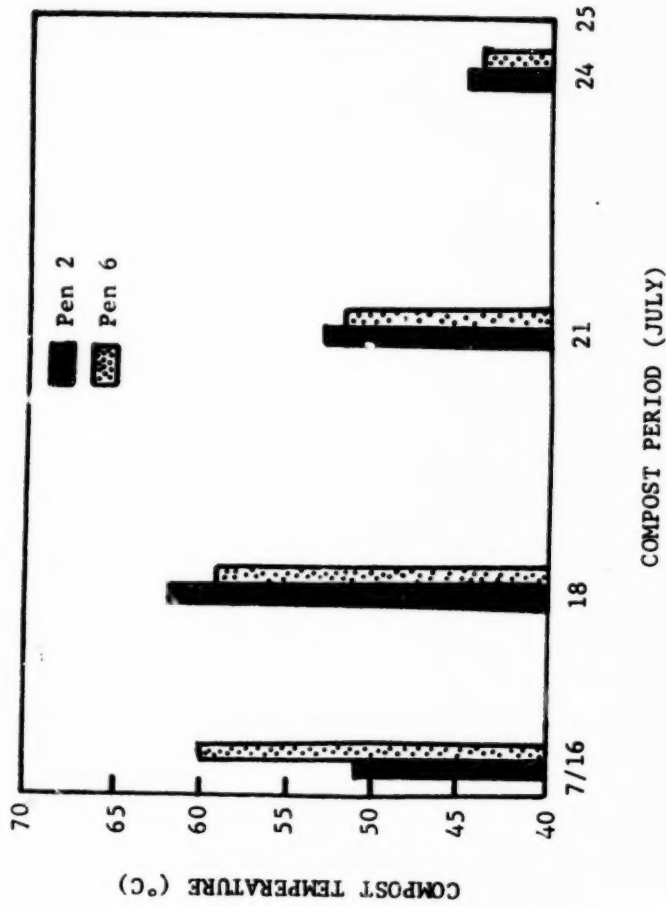


Figure 4. Average compost temperatures for litters seeded with Salmonella blockley (Each bar is a three day average temperature).